Section C
Landslides

Issue: How Well Do Current Forest Practices Maintain the Aquatic Habitat Functions Provided by the Natural Landslide Regime?

Forest Practices Advisory Committee on Salmon and Watersheds

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I. Current Scientific Findings

Landslides are the dominant erosional processes on steep forested slopes in western Oregon and throughout the Pacific Northwest (Swanson et al., 1987). A landslide is the movement of a mass of soil, rock or debris down slope. The typical landslide on steep forestlands begins as a relatively small and shallow feature, with typical dimensions of 3 feet in depth, 30 feet in width, and 40 feet in length, and a relatively planar failure surface (same shape as the ground surface). These small landslides can initiate debris flows (a semi-fluid mass scouring or partially scouring soils on the slope along its path). Upon entering stream channels, debris flows often carry large amounts of wood and are referred to as debris torrents. These features are described in more detail in the "Landslides and Stream-Channel Modifications" section.

Ancient, or relict, deep-seated landslides are perhaps more prevalent in the mountainous areas of western Oregon than previously thought. Many of these relict slide landforms cover tens to hundreds of acres. Relict landslides are often believed to have developed under different geomorphic or climatic conditions (Cruden and Varnes, 1996). A few of these deep-seated landslides have occurred over the past decade. Whether they were seismically induced as a result of high magnitude subduction zone earthquakes, wetter climatic periods (there is geomorphic evidence that the Pleistocene-Holocene epoch transition was a period of high rates of landsliding, possibly due to a wetter climate (Personius et. al., 1993)), or simply occur over long periods of time is unknown.

The vast majority of landslide studies have focused on the relationship of tree removal and road construction to debris slides (also referred to as shallow-rapid landslides) and not deep-seated landslides. Koler (1992) notes a handful of studies on deep-seated landslides, only one of which was designed to examine the effects of timber harvesting on an active earthflow in southwest Oregon. Swanston et al. (1988) found that in the years immediately after logging, the displacement rate of an active earthflow increased to 20mm/year. After three years the displacement rate returned to the pre-logging rate of 3mm/year. Because of the limited information and lack of applicable knowledge available on deep-seated landslides, this discussion will focus on shallow-rapid landslides.

Subsurface water and associated pore-water pressure is the most important factor associated with the occurrence of most landslides. Pore-water pressure affects the inter-grain forces within the soil. The higher the pore-water pressure, the lower the effective strength. Landslides may occur if there is either an increase in shear stress and/or a reduction in shear strength along the failure surface, or they may fail as a result of soil liquefaction (where the slope, or a portion of the soils on the slope behave more like a liquid, usually due to a sudden rise in pore pressure, or a rapid loss of cohesion or cementation (Terzaghi and Peck, 1967; Andersen and Sitar, 1995)).

Forest practices may alter both physical and biological (vegetative) slope properties that influence slope stability and the occurrence of shallow-rapid landslides. Physical alterations can include slope steepening, slope-water effects, and changes in soil strength. Most physical alterations are the result of roads and skid roads. On a unit-area basis, roads have the greatest effect on slope stability of all activities on forestlands (Sidle et al., 1985). Changes in vegetation can also have both hydrological and mechanical effects on the stability of slopes (Greenway, 1987).

Hydrological effects of vegetation on the hillslope include interception, evapotranspiration, and water routing. Interception is the storage of rain and/or snow on the leaves and branches of vegetation. Evapotranspiration is the removal of water from the soil or vegetation by plant growth or climate. Water routing is influenced by macropores and stemflow. Macropores can be relatively large (diameter measured in inches) pipe-like structures in the soil that can influence subsurface flow patterns during a rainfall event (Figure 1). Stemflow is the interception and routing of rainfall or snowmelt by the branches and stems and can create concentrated areas of flow.

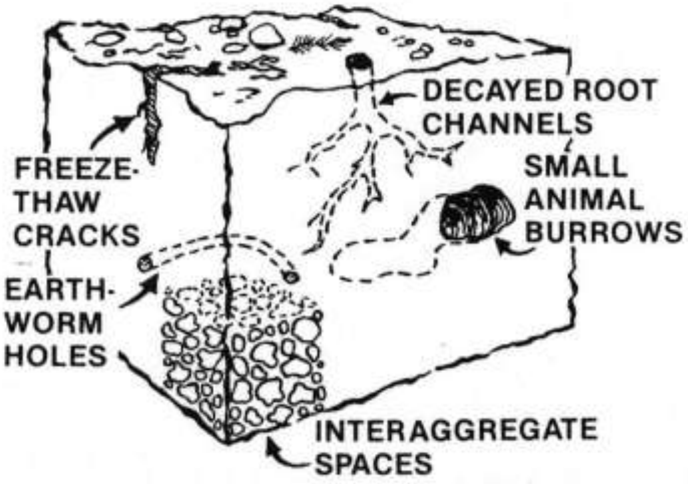

Figure 1: Illustration of various types of macropores in forest soils (from Sidle, 1980).

Mechanical effects of vegetation on slope stability are varying and sometimes contradictory. They include the following:

- root reinforcement: the penetration of roots into a potential landslide failure surface resulting in increased slope stability;
- buttressing and arching: trees at the base of a potential landslide act like piles and help stabilize the slope;
- surcharge loading by trees, logs and/or debris: the weight of these materials may add to the gravity force on the slope;
- wedging and loosening of soil by roots, thereby lowering the strength of the slope; and
- windthrow: soils are displaced and oversteepened, and also subject to vibration, as a result of the blow-down of trees.

Tree removal can also have varying effects on slope stability. They include the following:

- a reduction in interception or evapotranspiration.
- alteration of the forest canopy, thus changing water routing.
- the alteration and accumulation of snow and snowmelt patterns.
- a reduction in root reinforcement.
- a loss of buttressing and arching.
- a reduction in "surcharge loading."

The tree falling and log yarding process might effect soil by:

- alteration of macropores, thus changing water routing.
- a reduction in the soil infiltration rate due to compaction.

Most of the research on the effects of vegetation on forest slope stability in northwest forests has concentrated on the potential reduction in root reinforcement, or 'root strength.' The root strength concept is somewhat analogous to the effect of steel in reinforcing concrete. Most root strength models are two-dimensional and assume that roots penetrate the failure surface; that roots are anchored and do not move downslope with the landslide; and that the tensile strength of roots is fully mobilized during a mass wasting event (Greenway, 1987). Roots are fully mobilized if all of their potential strength is used by the weight of the material that is pulling in the downslope direction.

"The importance of roots to the stability of shallow soils on steep lands under intact coniferous forests and after the removal of forests in western North America has been elucidated by Swanston (1970, 1974); O'Loughlin (1974); Ziemer and Swanston (1977); Burroughs and Thomas (1977); Wu et al., (1979); Ziemer (1981); and Gray and Megahan (1981). These studies generally indicate that the continued stability of soils on many steep, forested slopes depend partly on reinforcement from tree roots, especially when soils are partly or completely saturated. After forest removal, the gradual decay of tree roots often predisposes forest soils to failure. Similar conclusions have been reached in Japan (Kitamura and Namba 1976; Endo and Tsuruta, 1969; Nakano 1971); and in New Zealand (O'Loughlin and Pearce 1976; Selby 1981; O'Loughlin et al.,1982)." (Sidle et al.,1985)

The magnitude of the effects of root strength on slope stability as the primary mechanism affecting slope stability on Pacific Northwest forestlands is not universally accepted. From a geomechanics perspective there are a number of reasons why some relatively simple models of root reinforcement to soil shear strength may not be valid. Soil strength values cited in the technical literature that are attributed to root reinforcement would lead to the conclusion that forested sites cannot fail and all high-risk sites that are harvested must fail (Skaugset, 1997). It is well documented from extensive ground-based landslide surveys that this is not the case (Hughes and Edwards, 1978; Ketcheson and Froehlich, 1978; Robison et al., 1999). Problematic assumptions in landslide analyses, inconsistencies in obtaining representative forest soil samples, difficult testing procedures, the importance of vegetation other than trees, and soil mechanics incompatibilities are just some of the factors that are causing some slope stability experts to reexamine the current root strength/slope stability paradigm.

Landslides and Stream Channel Modifications

The principal landslide-related effects of major storms, such as those which occurred in Oregon in February and November 1996, are both off-site and in-channel. Scour and deposition from landslides, debris flows, and torrents significantly modified stream channels (Robison et al., 1999). A potential concern with landslides is their effect on forest productivity. However, past studies in the Pacific Northwest have shown that even in areas with high landslide densities, generally less than two percent of the land area is directly impacted by landslides (Ketcheson and Froehlich, 1978; Ice, 1985).

In steep terrain, small shallow landslides can quickly transform into debris flows. A debris flow occurs if the landslide moves down slope as a semi-fluid mass, scouring or partially scouring soils on the slope along its path. A debris flow is any movement below the initial landslide and upslope of a stream channel. Upon entering and continuing down a stream channel, debris flows are sometimes called debris torrents (Van Dine, 1985; Robison et al., 1999). In western Oregon, landslides initiate most debris flows and torrents (Swanson and Lienkaemper, 1978). Debris torrents in the Pacific Northwest typically contain significant amounts of large wood. Debris flows and debris torrents travel varying distances and result in variable degrees of impact depending on channel slope, confinement, layout of the channel network, and other characteristics (Fannin and Rollerson, 1993).

While landslide features may constitute a very small percentage of the total land area, they can have varying degrees of impacts on a significant portion of the channel network (Swanson et al., 1987). Robison et al. (1999) found that anywhere from 40 to 80 percent of the entire channel network experienced severe impacts (defined in this study as major scour or deposition from debris torrents or dam break floods) in areas that experienced the most severe storm impacts (the five “red zone” areas that are areas with high levels of observed slides). However, in nonred zone areas very little, if any, of the stream channel network had noticeable impacts.

Small streams in steep terrain supply wood, sediment, and relatively cool water to larger fish bearing streams. In addition, small streams often provide habitat for critical life stages of fish and other aquatic organisms. Landslides and debris flows provide most of the sediment input into small streams in steep forested watersheds (Benda and Dunne, 1987). Past studies have documented channel changes for small and large streams resulting from high water and landslide activity including channel scour and fill, channel widening, changes in channel longitudinal profile, and decreases in ecological stability (Lyons and Beschta, 1983; Kaufmann, 1987; Lamberti et al., 1991; Reeves et al., 1995). Reeves et al. (1995) suggests that the input of spawning gravel, large wood, and floodplain sediment from naturally occurring landslides is an important factor for maintaining productive fish habitat. It is hypothesized by Reeves and others that in many cases, the short-term disturbance caused by a landslide may be necessary to improve long-term aquatic habitat conditions.

Debris flows and torrents commonly transport many times more sediment through scour of hillslopes and channels than the initiating landslide. In some cases, an initiating landslide of 10 cubic yards or less may become a debris torrent moving thousands of yards of material into and through portions of the channel network. Debris flows and torrents tend to deposit sediment when channel gradients drop to less than six percent (Benda and Cundy, 1990). They also tend to stop in the form of a debris jam at tributary junctions where the junction angle is greater than 70 degrees (Benda and Cundy, 1990).

While woody debris carried in debris flows and torrents may have long-term benefits for aquatic habitat, it may also create a public safety hazard in some cases. Harvey and Squier (1998) found that "slash piles in the channel, or abundant slash, which can form temporary debris jams in the channel, can increase the severity of debris flows." Wood is also associated with "migrating organic dams" that can move long distances down relatively gentle stream channels (Coho and Burges, 1994).

Landslide Studies

Numerous studies have examined the differences in landslide rates between forested and recently harvested sites (Table 1, page C-33). Table 1 lists studies throughout the Pacific Northwest in which landslide rates (number of slides for a given time period) and/or densities (number of slides per unit area) under different stand treatments were compared directly. In all, there were 35 forest treatment comparisons found from 24 published or semi-published studies. Several compilations of past studies have been used to draw conclusions about the effects of forest harvesting on landslide rates (Ice, 1985; Sidle et al., 1985; and Meehan et al., 1991). As Table 1 indicates, most studies (28 of the 35 comparisons on Table 1) are based partially or completely on aerial photo interpretation. In the past, there has been debate on whether it is appropriate to use aerial photos to compare recently harvested area landslide densities and erosion rates with those areas that contain mature forests. For instance, a classic exchange occurred in a discussion on a research paper by Pyles and Froehlich (1987), followed with a reply by Wolfe and Willams (1987). In the discussion Pyles and Froehlich laid out, on theoretical grounds, several reasons why landslides cannot be reliably detected on aerial photos due to photo angles and the obscuring effect of tall trees. In reply, Wolfe and Williams pointed out that Pyles and Froehlich had no empirical data to verify their findings. In particular they stated:

> "Unfortunately Pyles and Froehlich have failed to provide documentation of these statements. It certainly would be of value to know how dramatic the differences are between these two types [ground vs. air based] of inventories."

The study by Swanson et al. (1977) utilized an aerial photo inventory to determine landslide frequency in clearcut areas, and a ground survey of 1,300 acres to find landslides in older forests. The study was conducted in the Mapleton Ranger District of the Siuslaw National Forest and overlapped one of the study sites used in Robison et al. (1999). Swanson found that erosion rates were higher in clearcuts than unmanaged stands. The clearcut erosion rates ranged from 1.2 to 1.3 times higher than unmanaged stands for most land types. For the land types most prone to landslides (i.e., steep slopes), clearcut erosion rates were 4.0 times higher than in unmanaged stands. Since not all landslides can be detected on aerial photos even in clearcuts, and the study compares an air-based clearcut sample to a ground-based in forest sample, these erosion rate ratios may be artificially low.

Ketcheson and Froehlich (1978) field-investigated small watersheds (100 acres or less) that were unaffected by forest roads in an area near Mapleton, Oregon. The watersheds were inspected by walking on one side of the drainage and examining headwalls. They found 104 landslides in a 1,076 acre study area. Landslide data were collected on failures as old as 15 years with unspecified dating techniques. This study found that the erosion rate in clearcuts was approximately 3.7 times higher than that of undisturbed forests.

There are also landslide studies that have attempted to understand the behavior of landslides rather than simply comparing rates between forests of different ages. A study site located northeast of Coos Bay in Oregon has been the location of several of these types of studies (Montgomery et al., 1997). Detailed field measurements of a specific landslide-prone site have been made for over a decade. The study site is covered with an array of instruments to determine soil pore-water pressure, interactions between rock and soil water, long-term weathering rates, and many other physical processes. The role of vegetation in the stability of this site is also being examined. A debris slide/flow occurred at this site in the November 1996 storm and is providing a unique opportunity for the study of specific factors associated with landslide initiation.

Information from this site was also used to help develop a topographic model for the assessment of landslide hazard areas (Montgomery and Dietrich, 1994). This particular model uses a geographic information system (GIS) to calculate areas of high landslide potential based on slope steepness, slope convergence (watershed area), and steady-state rainfall. Other slope stability factors such as soil depth and potential root reinforcement can also be added to the model when site-specific data is available. The Bureau of Land Management (BLM) and at least one industrial private forestland company have utilized this model to help identify and manage landslide hazard areas.

The OSU headwall leave area study (Martin, 1997) also was conducted in the Mapleton area. The headwall leave area technique has been used to try and reduce landslides associated with timber harvesting. Headwalls (very steep concave slopes that contain no channels) are first identified. Once identified, trees on these headwalls are protected from harvest activities. Martin (1997) identified landslides in forested headwalls, clearcut headwalls, and headwalls protected with leave areas. They found no statistical difference in landslide occurrence between mature forests, leave areas, and clearcuts. However, the period of time such sites were subject to landslide producing storms was longer for the forested headwalls, a factor which may have overestimated the comparative failure rate of the forested headwalls.

The headwall leave area technique is recommended by Forest Ecosystem Management Assessment Team (FEMAT) (1993) for federal forestlands based on a study by Swanson and Roach (1987). Specifically, FEMAT recommended that minimum leave areas of three to ten acres in steep headwall areas be protected from timber harvesting. Due to the small amount of harvesting on federal lands, and the fact that many headwall leave areas overlap with areas receiving riparian protection near seasonal streams, there is little information available to evaluate the effectiveness of the headwall leave area technique. Anecdotal evidence from Swanson and Roach (1987) and Martin (1997) also indicate that headwall leave areas may increase the risk of windthrow, and therefore probably landslide occurrence as well.

Landslide inventories based totally on aerial photographs have limited use for identifying those landslides most common in steep forested terrain, especially in areas with dense forest cover. In Robison et al. (1999), aerial photographs of a number of different scales were obtained for the eight study areas that were inventoried (1:6000, 1:12000, and 1:24000). Although aerial photographs have utility for many purposes, their use for identification of shallow-rapid landslides results in biased and incomplete landslide inventories. This bias significantly underestimates the landslide frequency and erosion volume across all forest stand age classes. For example, in the Mapleton and Vida study areas of Robison et al. (1999), 72 percent of all landslides identified from the ground-based survey were not detected using 1:6000 aerial photographs. The majority (72-98 percent) of shallow-rapid landslides were not visible on aerial photographs of any scale. In terms of erosion volume, the landslides that were not identified from aerial photographs accounted for 53 percent and 41 percent of the total landslide related sediment volume delivered to stream channels in the Vida and Mapleton study areas, respectively (1:6000 scale). Landslide identification is most problematic in areas with mature or semi-mature timber. For instance, roughly 50 percent of the landslides were detected in recently harvested areas (0-9 years old) but less than 5 percent of the landslides were detected in mature stands (older than 100 years) (Robison et al., 1999). Aerial photo analysis will significantly magnify landslide density and erosion volume per unit area for recently harvested areas relative to older forested areas.

As a result of this bias in aerial photo inventories, comparisons that use this method result in greater apparent increases in landslide density and erosion volume associated with stands recently clearcut than do ground–based inventories. Table 2 shows the average and range of landslide densities for the various studies given in Table 1. The average ratio between clearcut and mature landslide densities for aerial photo inventories is about five times the average for the ground-based inventories (15-fold increase versus 3-fold increase).

Table 2. Increase in landslide occurrence after clearcutting as reported by studies (from Table 1) using different methods for landslide identification. (See note with Table 1 for the method definitions.)

Method	Number of Comparisons	Average Ratio	Maximum Ratio	Minimum Ratio
Air	6	15.8	30	6.1
Ground	6	3.3	8.0	0.8
Mixed	7	5.4	17.0	1.2
Air/Field Visits	12	9.7	23.5	0.0
Air/Size	4	7.7	13.5	2.6
All Studies	35	8.6	30.0	0.0

In light of the limitations of aerial photographs, the few ground-based studies that have been completed offer the most reliable conclusions in terms of landslide-rate comparisons between clearcuts and mature forest conditions. Of the studies listed in Table 1, only six are completely ground based (four different study areas within Robison et al. (1999) are each considered as a separate ‘study’). The rate of landslides in recently harvested areas ranged from 0.8 to 8.0 times that observed in mature forests for these six studies. Thus, while it is possible during the period immediately following harvesting that landslide rates will remain unchanged (Elk Creek study area in Robison et al. 1999), it is much more likely that the landslide rate will increase. These studies, however, only address landslide rates during the first few years after harvest. Landslide rates in areas with established second-growth forests have received very little attention in past landslide studies. Robison et al. (1999) is the only ground-based study listed here that examines landslide rates in forests between 10 and 100 years old. These forests were generally found to have landslide densities and erosion volumes lower than that of mature forests.

The conclusions from Robison et al. (1999) only apply to single, extreme storm events, however, and cannot address the issue of long-term effects of harvesting on the landslide regime. Sidle et al. (1985) provided a summary of the then current state of knowledge about long-term landslide rates as influenced by forest harvesting:

> “The long-term effect of timber harvesting on erosion caused by debris avalanches cannot readily be ascertained from landslide inventories (except by repetition throughout one or more harvesting rotations). . . . Clearcutting may actually only change the timing of natural landsliding, and over long periods the total erosion from shallow-rapid failures may be independent of timber removal (Froehlich 1978, Swanson et al. 1981, Swanson and Frederiksen 1982). After harvesting, an acceleration in soil mass movement is frequently observed for 10 to 15 years, but subsequent erosion (before the next cutting) may actually decline below “natural” levels. This hypothesis has not been substantiated by field data.”

For a single extreme storm event, Robison et al. (1999) observed a reduction in landslides in most study areas for second growth forests (i.e., 10-100 year age class). While this does not specifically address the question of how long-term rates of landslides are influenced by harvesting, it does give more credibility to the hypotheses stated above that erosion rates for second-growth forests may decline below “natural” levels. It should be noted, however, that even though the ODF study looked only at a single storm rather than at landslides occurring over a longer time period, it is believed that the largest storms result in the occurrence of most shallow-rapid landslides (Ice et al., 1988).

There are others that argue for an alternative hypothesis, namely, that harvesting can dramatically increase the rate of landsliding relative to “natural” levels and that over the long-term, timber harvesting causes an increase in erosion to a degree that landscapes are denuded of soil (David Montgomery, MOA Landslide Workshop). Reneau and Dietrich (1991) analyzed the colluvial deposits in nine hollows in the Oregon Coast Range located in roadcut exposures. These hollows had maximum depths between 4.3 to 13.6 feet, slope steepness between 53 and 75 percent, and drainage areas between 0.02 to 1.01 acres. Using radiocarbon dating from charcoal deposits throughout a cross section of the colluvial deposits, they concluded that the average residence time of the sediment in these hollows was 5,000-6,000 years. This corresponds to a weathering rate of 0.062 to 0.130 mm per year, which is consistent with estimates of weathering rates for the

Oregon Coastal Range (Reneau, 1988). If shallow-rapid landslides “naturally” recur on a given site every 5,000-6,000 years, and current harvest rotations are significantly shortening this recurrence interval, it is possible that these portions of the landscape (i.e. areas where landslides are the dominant erosional process) are being denuded of soil over the long-term.

When a landslide-prone site excavates (i.e., soil moves off the site exposing bedrock or a partially-filled void on the hillslope or hollow), it takes a certain amount of time to recharge (i.e., refill with soil, either through bedrock weathering or adjacent soil creep into the excavated area). There are a number of scientific opinions on this “time to recharge”, but there is very limited data available to resolve the debate. Results from Robison et al. (1999) suggest that the time to recharge (or time to fail) is variable, depending on slope steepness and site-specific geomorphological processes. For example, modeling results from Montgomery and Dietrich (1994) has shown that steeper slopes with greater drainage areas have a greater risk of failure (and thus may be expected to fail more frequently) than less-steep slopes with smaller drainage areas. The data provided by Reneau and Dietrich (1991) are from nine sites that could be considered to have less steep slopes and smaller drainage areas. Of the nearly 500 landslides identified in Robison et al. (1999) that were not associated with roads, less than 10 percent had maximum depth, slope, and drainage area characteristics similar to these nine sites. The 5,000 to 6,000-year “time to recharge” from Reneau and Dietrich (1991), if correct, may only apply to a small proportion (less than ten percent) of the total landslide population. Since this sub-set of landslides has less steep slopes and smaller drainage areas, it makes sense that they would occur less frequently than the majority of shallow-rapid landslides.

That the sites most susceptible to landslides may fail more frequently than every 5,000 to 6,000 years is not incompatible with the estimate of the weathering rate (0.062 to 0.130 mm per year) calculated by Reneau (1988). Comparing this weathering rate to the total erosion calculated in Robison et al. (1999) would mean that about 20 years of weathering was delivered to stream channels in a single storm event, at least for the coastal red-zone study areas. The largest storm event previous to 1996 was in 1964 (32 years earlier), which translates roughly to 63 percent of the total weathering since 1964 (20/32 years) occurred in 1996. These calculations are consistent with the belief that the largest storms result in the occurrence of most shallow-rapid landslides (Ice et al., 1988).

While there may be merit to both the “timing” and “denuding” hypotheses, there are currently no studies that have been effective in confirming or disproving either one. It will likely take continued research over long periods of time to resolve this scientific debate.

The Independent Multidisciplinary Science Team (IMST) report includes the following summary information about managing slope failures and the movement of material into streams:

“Slope failure is a natural process and it can have both positive and negative effects on fish habitat. The technical basis for managing roads to reduce or minimize slope failure is well developed. The technical basis for managing nonroad-related slope failure is much less well developed, except under extremes of site conditions. Although speculative, we believe maintenance of functional riparian zones along channels where debris torrents may occur can mitigate their destructive force, and increase the positive effects they may have."

II. Watershed-scale Effects

Forest Management

Potential watershed-scale effects of forest management may influence both the quantity and quality of landslides. Regardless of which hypothesis is applied (timing versus denuding), if a relatively high percentage of the high-risk areas in a given watershed is in a very young age class, the risk of landslide occurrence is increased. The quality of landslides can also be influenced at a watershed-scale if a relatively large portion of the land area in the upper reaches of a watershed is in a young age class. Younger forests will not provide as many of the larger key pieces of wood to areas where landslides and debris flows occur as compared to what an older forest would provide. Leaving trees and/or large down wood (in key areas) from the previous stand at the time of harvest may mitigate these effects.

Other Land Uses

Any land use that alters either the physical or biological (vegetative) slope properties can influence slope stability. Urban and rural development that creates or increases a road network and the percent of impervious surface in a given watershed can have a significant effect on the slope properties in terms of water routing. Macropore alterations and the routing of sub-surface flow into areas where water does not normally flow are examples of how development can influence landslide occurrence. The conversion of forests to some other land use will also influence the hydrological properties of the watershed by reducing the interception and evapotranspiration capacity of the soil (other effects of vegetation removal listed on page C-2). On a site-specific basis, rural and urban developments have the potential to result in much greater slope and drainage alterations than do forest practices. Development often results in extensive excavation into hillslopes and the creation of impervious surfaces that significantly influences water routing and other hillslope properties.

III. Objectives of the Current Measures and Rules

Oregon Plan Objectives

The Oregon Plan for Salmon and Watersheds (OPSW) does not include any specific objectives for the management of landslides and/or debris flows. Riparian functions that are associated with this issue include sediment and large wood, which are discussed in other issue papers.

Forest Practices Act Objectives

OAR 629-630-000 – Purpose (Harvesting Rules)

(1) Harvesting of forest tree species is an integral part of forest management by which wood for human use is obtained and by which forests are established and tended.

(2) Harvesting operations result in a temporary disturbance to the forest environment.

(3) The purpose of the harvesting rules is to establish standards for forest practices that will maintain the productivity of forestland, minimize soil and debris entering waters of the state, and protect wildlife and fish habitat.

IV. Description of Measures and Rules

Oregon Plan Measures

The Oregon Plan for Salmon and Watersheds (OPSW) does not include any specific measures for the management of landslide and/or debris flow occurrence. ODF 61S (Analysis of "Rack" Concept for Debris Flows) is a voluntary measure that addresses the issue of landslide and debris flow quality. Under this measure:

“Oregon Forest Industries Council (OFIC) members will conduct surveys to determine the feasibility and value of retaining trees along small Type N streams with a high probability of debris flow in a "rack" just above the confluence with a Type F stream. The rack would extend from the Riparian Management Areas (RMA) along the Type F stream up the Type N stream some distance for the purpose of retaining trees that have a high likelihood of delivery to the Type F stream.”

The primary goal of this measure is to influence the type of debris that is transported by the landslide, and not necessarily to influence the movement of individual landslides. ODF 20s is another measure that addresses the quality of landslides and debris flows. This measure involves the placing of large wood in stream channels that are potential debris flow paths (discussed in the Riparian Function issue paper).

Forest Practices Act Standards and Rules

OAR 629-600-100 - Definitions

(27) "High-risk areas" are lands determined by the State Forester to have a significant potential for destructive mass soil movement or stream damage because of topography, geology, biology, soils, or intensive rainfall periods.

(28) "High-risk sites" are specific locations determined by the State Forester within high-risk areas. A high-risk site may include, but is not limited to: slopes greater than 65 percent, steep headwalls, highly dissected land formations, areas exhibiting frequent high intensity rainfall periods, faulting, slumps, slides, or debris avalanches.

OAR 629-630-100 Skidding and Yarding Practices

(3) Operators shall locate skid trails where sidecasting is kept to a minimum.

(4) Operators shall locate skid trails on stable areas so as to minimize the risk of material entering waters of the state.

(5) Operators shall avoid excavating skid trails on slumps or slides.

(6) Operators shall limit cable logging to uphill yarding whenever practical. When yarding across high-risk sites in the Northwest Oregon Region or Southwest Oregon Region, or when downhill cable yarding in any region is necessary, operators shall use a layout and system which minimizes soil displacement.

OAR 629-630-500 Harvesting on High-risk sites in Western Oregon

(1) In the Northwest Oregon and Southwest Oregon regions, operators shall obtain prior approval from the State Forester before conducting harvesting operations on high-risk sites.

(2) Written plans, where required for harvesting on high-risk sites, will describe how harvesting operations will be conducted to minimize impact upon soil and water resources.

OAR 629-630-600 Felling; Removal of Slash

(2)(b) On steep slopes, use felling practices such as jacking, line pulling, high stumps, whole tree yarding, or stage-cutting as necessary and feasible to prevent damage to vegetation retained in riparian management areas, soils, streams, lakes and significant wetlands.

(3) Operators shall minimize the effects of slash that may enter waters of the state during felling, bucking, limbing or yarding by:
(b) Not allowing slash to accumulate in Type N streams, lakes or wetlands in quantities that threaten water quality or increase the potential for mass debris movement.

High-risk sites are designations used by ODF for locations that are vulnerable to landslides capable of causing damage to natural resources (specifically water quality and fish habitat). Evaluating the accuracy of these high-risk site determinations is critical, since there are specific rules and administrative procedures that apply only after high-risk sites are identified. High-risk sites have been designated as having the following landform characteristics:

Actively moving landslides;
Any slope steeper than 80 percent;
Concave slopes steeper than 70 percent;
Slope breaks where the lower slope exceeds 70 percent;
Inner gorges with slopes steeper than 60 percent; and
Other sites determined to be of marginal stability by ODF personnel.

The Oregon Board of Forestry adopted most of the current landslide prevention rules in June 1983. Rules for harvesting on high-risk sites were adopted in 1985. The forest practice rules for harvest operations are intended to minimize both surface and mass (landslide) erosion. Harvest practices are subject to added regulation if they affect high-risk sites.

Standard practices for the protection of high-risk sites during forest harvesting and stand management activities on private lands in Oregon include:

- Felling timber to minimize ground disturbance and slash accumulations on high-risk sites;
- Not building skid trails on high-risk sites;
- When yarding across high-risk sites, providing at least one end suspension and ensuring that logs do not gouge soils;
- Not building landings on high-risk sites, and avoiding placement of landing debris or landing drainage on high-risk sites; and
- Replanting as soon as possible after logging.

The following additional practices have at times been used to protect high-risk sites but are not considered standard practices or requirements in most cases:

- Leaving nonmerchantable trees and understory vegetation relatively undisturbed;
- Avoiding prescribed burning;
- Avoiding use of herbicides;
- Leaving a buffer area around headwalls (headwall-leave areas);
- Thinning the stand instead of clearcut harvesting to retain some root strength; and
- Not harvesting the area.

V. Evaluation of the Measures and Rules

Voluntary Measures

The Oregon Plan for Salmon and Watersheds (OPSW) does not include any specific measures for the management of landslide and/or debris flow occurrence. ODF 61S (Analysis of "Rack" Concept for Debris Flows) is a voluntary measure that addresses the issue of landslide and debris flow quality; however, there is no information on the use or effectiveness of this measure. Riparian functions that are associated with this issue include sediment and large wood, which are discussed in previous issue papers. The evaluation of measure ODF 20S is considered in previous issue papers (specifically, large wood and stream temperature).

Current Rules

The following are conclusions from Robison et al. (1999). These findings include the most current information addressing the adequacy of the forest practice rules related to landslides and debris flows.

Identification of Landslides and Landslide Hazards:

- Landslide inventories using only aerial photographs without significant on-the-ground surveying do not identify the majority (over 75 percent) of shallow-rapid type landslides, and on average, detect about 50 percent of the erosion volume associated with landslides. The fact that the forest canopy can significantly obscure the ground surface makes it difficult to identify or accurately measure landslides in forested terrain. Therefore, landslide inventories based solely on aerial photographs have limited use for identifying those landslides most common in steep forested terrain, especially in areas with dense forest cover.
- Air photo landslide inventories, on average, overestimate the ratio of landslide occurrence in clearcuts versus mature forests by a factor of five. Robison et al. (1999) shows as much as a ten-fold overestimation of this ratio.
- Coarse-scale digital elevation models (30-meter) underestimate slope steepness, especially in areas with irregular, steep slopes.
- In the forests of western Oregon, ground-based investigation provides the most reliable information on landslide occurrence and their characteristics.
- Slope steepness, landform shape, and drainage area above the landslide are important factors for determination of those sites most susceptible to landslides.
- The factors currently used in the determination of high-risk sites could be modified to improve accuracy in identifying those sites prone to debris slides and flows, and may need to include differences by geologic unit.
- The highest hazard for shallow-rapid landslides in western Oregon occurs on slopes of over 70 percent to 80 percent steepness (depending on landform and geology). There is a moderate risk of these landslides on slopes of between 50 percent and 70 percent.
- Subsequent scour by debris flows and torrents, and not the initial landslide volume, represent most (90 percent) of the landslide-related sediment that is carried into and through stream channels.

Landslides and Forest Stand Condition:

- Timber harvesting can affect landslide occurrence in areas with a moderate to high landslide risk. Higher landslide densities and erosion volumes were found in stands that had been harvested in the previous nine years, as compared to forests older than one hundred years, in three out of four ODF storm monitoring study areas. Forested areas between the ages of 10 and 100 years typically had lower landslide densities and erosion volumes than found in the mature forest stands (Robison et al., 1999).
- There is significant background landslide risk on very steep slopes, especially in certain geologic formations, where major storms and landslide processes are the dominant means by which the landscape is shaped.

- Landslides from recently harvested and older forests can have similar dimensions, including depth, initial volume and debris flow volume (Robison et al., 1999).
- Variability in both storm and site characteristics can be a dominant influence on landslide occurrence.

Landslides and Timber Harvesting Practices:

- In the locations adjacent to landslides surveyed in the ODF storm monitoring study ("the ODF study"), landowners and loggers complied with the forest practice harvesting rules (as changed in 1983) to minimize ground disturbance and slash accumulations on landslide prone sites.
- Any disturbance that removes vegetation on steep, landslide-prone locations results in increased landslide occurrence. Both the length of time these locations experience periods of reduced forest cover and the extent of lands with reduced vegetative cover can affect landslide density and erosion rate.
- Landscape level disturbances can result in large, contiguous areas in a condition susceptible to landslides.
- Alternative management strategies for high-risk sites should be carefully monitored. This will take considerable time, since landslides are a geologic process (variable in both time and space). The effectiveness of any specific practices, therefore, will be difficult to evaluate until the landscape has experienced major storms and/or prolonged exposure to geologic processes.

Stream Channel Impacts:

- In the ODF study, stream channel impacts varied greatly by study area and were not directly related to the number of landslides. Large, up-slope landslides originating above small channel junction angles ($<70^o$) and steep channel gradient slopes resulted in the greatest stream channel impacts.
- Debris torrents reduce stream shading, especially when they travel through younger stands.
- Debris torrents have only a minor effect on active channel width.
- The Benda-Cundy model provides a reliable tool for determining maximum potential travel distances of "typical" debris flows and torrents from forested slopes. Less than 10 percent of the total landslides in the ODF study traveled further than predicted by the Benda-Cundy model (Benda and Cundy, 1990). The debris torrents that traveled further than predicted were on average larger and had younger riparian vegetation near their terminus. Thus, in terms of determining landslide run-out distance, channel junction angles and channel gradient are the primary factors, while landslide volume and composition of the riparian area along debris torrent-prone channels may be important secondary factors.
- In the ODF study, slash in the channel was different by stand age class for the Elk Creek and Scottsburg areas. However, whether these differences in slash resulted in increased travel distances by debris torrents could not be determined.

Independent Multidisciplinary Science Team (IMST) Recommendations

The IMST made a total of 19 recommendations in its forestry project report of September 14, 1999. Three of their recommendations are directly or indirectly related to the effects of landslides on the sediment regime or on aquatic habitat. These three recommendations are listed below, followed by the applicable issue paper options.

Recommendation 2. ODF should develop a policy framework to encompass landscape (large watershed) level planning and operations on forests within the range of wild salmonids in Oregon.

Landslides Issue Paper Option(s):
Option # 46, method 3 (geoscientist evaluation of debris flow hazard)
Option # 47, method 4 (limiting young age class over watershed)

Recommendation 13. Retain trees on "high-risk slopes" and in likely debris torrents tracks to increase the likelihood that large wood will be transported to streams when landslides and debris torrents occur.

Landslides Issue Paper Option(s):
Option # 45, all methods (to identify sites prone to landslides)
Option # 46, all methods (to identify debris flow-prone channels)
Option # 47, method 2 (practices based on geoscientist hazard and risk evaluation)
Option # 47, method 3 (leaving some trees)
Option # 47, method 5 (prohibition of harvesting)
Option # 61, leaving trees in or near debris flow-prone channels

Recommendation 14. Continue to apply the current best management practices (BMP) approach to the management of forest lands with significant landslide potential, and develop a better case history approach for evaluating the effectiveness of BMP in this area.

Landslides Issue Paper Option(s):
Option # 45, all methods (to find high-risk sites)
Option # 47, method 1 (current practices with possible minor modification)
Option # 47, method 3 (leaving some trees, [and monitoring for case studies])

VI. Possible Additional Measures and/or Rules

Option #45: Identifying High-Risk Sites

Objective:
Ensure that all landslide-prone locations (now called "high-risk sites") are identified prior to operations.

Description:
The current rules require that where high-risk sites are identified by the forest practices forester (FPF), specific harvesting practices must be utilized. Each FPF is responsible for identifying high-risk sites either before or during harvest operations. The FPFs currently do not have the tools or time to systematically inventory the landscape to be sure that all high-risk sites are identified. This option proposes creating additional tools to ensure that all high-risk sites are identified prior to operations.

Methods/Approaches:
Current guidance could be modified to better identify those sites with the highest hazard for shallow landslides. Note that these sites are most appropriately called “high hazard.” Hazard is the presence of a conditions that might lead to some potentially damaging or dangerous outcome (i.e., steep slopes that could produce a landslide. Risk is a measure of the likelihood that this undesired outcome will both occur and will also have consequences (i.e., the landslide occurs and becomes a debris flow that scours stream channels). Hazards exist that have very low risk to resources (steep slopes above a large bench, where there is no potential for a debris flow or other sediment will enter stream channels).

Three specific methods are proposed for consideration as follow:

1. As per current practice, ODF notifies operator that high-risk (hazard) sites meeting set criteria are in the proposed operation area and provides operator with information on high-risk (hazard) site characteristics. ODF bases this notification on an office screening using available maps, or with a field pre-operation inspection as time permits. The office screen is intended to be a coarse screen only. As per current practice, it is the operator’s responsibility to more specifically locate sites within the operation area.
2. Operator identifies presence of high-risk (hazard) sites using criteria in rule form. The difference between method 1 (above) and this method is that the operator would notify ODF of the presence of sites during the notification process.
3. High-risk (hazard) sites are identified by geoscientist working for the operator. High-risk (hazard) site determinations would be based on ODF criteria and professional judgement.

ODF would refine the current high-risk (hazard) site criteria based on results from the “storm impacts” study. High-risk (hazard) sites for methods would be slightly modified from current guidance as follow:

1. actively moving landslides;
2. concave slopes steeper that 70 percent for most areas, except 65 percent for Tertiary sedimentary rocks in western Douglas, western Lane and Coos counties. Western means west of I-5;
3. any slope steeper than 80 percent (except 75 percent for Tertiary sedimentary rocks) excluding competent rock outcrops; and
4. other sites determined to be of marginal stability by ODF (applies only to method 1).

Note that there are certain landforms with high landslide hazard that would not be identified using the criteria listed above. Nor does this criteria address “risk” or the potential consequences of these landslides. Most foresters do not have the geologic interpretative skills to make these more complicated judgements.

Method 1

Benefits:
This method provides a simple, fairly conservative screen for high-risk (hazard) sites.

Costs:
This method results in a fairly low cost to operators. It also may provide the least certainty and consistency in high-risk (hazard) site identification. Many sites identified as high hazard will in fact be relatively stable, and there will be some sites that are not identified that will fail. Operators will still be required to more specifically locate high-risk (hazard) sites on the ground. Requiring the operator to identify these sites is problematic, since most lack the skills needed for this work, nor does ODF have the resources to consistently identify sites.

Method 2

Benefits:
This method also provides a fairly simple means for identification of high-risk (hazard) sites. It is likely that with either methods, 1 or 2, operators would have the final responsibility to show location of high-risk (hazard) sites in the written plan. This method could provide more consistency in high-risk (hazard) site identification.

Costs:
This method results in the lowest cost to ODF and an intermediate cost to landowners. Landowners that fail to identify high-risk (hazard) sites may incur added liability for forest practices violations associated with not identifying high-risk (hazard) sites. Again, many sites identified as high hazard will in fact be relatively stable, and there will be some sites that are not identified that will fail. Some sites may be missed, since other marginally stable sites (as per criteria 4 above) would not be identified. Requiring the operator to identify these sites is problematic, since most lack the skills needed for this work.

Method 3

Benefits:
This might result in the most complete identification of high hazard locations. It will also allow characterization of risk level, so that practices could be based on the level of risk to resources. If the geoscientist also develops management measures under Option 47, this method should result in more appropriate harvesting practices being applied to existing high-risk (hazard) sites. Further characterization of the hazard may help define the appropriate regulations for these locations, and result in a more targeted application of appropriate harvesting practices.

Costs:
On the ground geoscientist investigations place an additional expense on the operator. Because of incomplete scientific understanding about mechanisms that cause landslides to occur, it is not possible to identify all the locations where landslides will occur.

Option #46: Identify Debris Torrent Risk for Streams

Objective:
Identify stream channels prone to debris flows and torrents.

Description:
To move large wood from headwall or zero-order channels into larger streams requires a debris flow or torrent. Only certain stream channels are at risk for debris flows. Finding those channels that are capable of moving large wood to Type F streams could make it possible to focus riparian prescriptions on those streams where greater benefits to aquatic habitats and salmonids are more likely. The appropriate management of riparian areas in these areas may be different from other areas since wood on steep slopes can move long distances down these slopes (possible channel entry from greater distances). If these streams are to be managed in an optimal manner for the maintenance and recovery of salmonids, they must first be identified. Current technology will allow reasonably accurate identification of these streams and facilitate the application of appropriate riparian management measures.

Methods/Approaches:
ODF is currently completing a debris flow mapping project that includes different hazard categories (low, moderate, high and extreme). This could be combined with ground verification that there is an actual risk of debris flows entering stream channels.

As with Option 45, three specific methods are proposed for consideration as follow:

1. ODF notification to operator that debris flow-prone channels are in the proposed operation area based on current debris flow hazard maps. This is intended to be a coarse screen only, it would be the operators responsibility to field verify these conditions.
2. Operator identifies presence of debris flow-prone channels using criteria in rule form.
3. Debris flow-prone channels are identified by geoscientist working for the operator using professional judgement. Relative risk of delivery to fish bearing stream channels is also identified.

Method 1

Benefits:
This method could provide a simple screen for debris flow-prone channels, based on debris flow hazard maps.

Costs:
This method results in the lowest initial cost to operators. It also may provide the least certainty and consistency in identification of debris flow-prone channels. Determination of actual debris flow hazard on the ground would be problematic.

Method 2

Benefits:
This method also provides a fairly simple means for identification of debris flow-prone channels.

Costs:
This method results in the lowest cost to ODF and an intermediate cost to landowners. Developing a simple criteria for field determination of debris flow-prone channels could be based upon the Benda-Cundy (1990) model. With this method, operators that fail to identify debris flow-prone channels may incur added liability for forest practices violations associated with not identifying high-risk (hazard) sites.

Method 3

Benefits:
This might result in the most complete identification and characterization of debris flow-prone channels. It will also allow characterization of risk level, so that practices could be based on the level of risk to resources. If the geoscientist also develops management measures, this method should result in more appropriate practices being applied debris flow-prone channels.

Costs:
On-the-ground geoscientist investigations place an additional expense on the landowner or operator. Because of incomplete scientific understanding about mechanisms that affect debris flow movement, it is not possible to identify all the locations where debris flows will occur, or how often they occur. If management prescriptions include conifer retention on high-risk (hazard) sites or along debris flow-prone streams, additional landowner costs will be incurred.

Option #47: Management of High-Risk Sites

Objective:
Moderate or limit management activities believed to increase the occurrence of slope failure.

Description:
This objective is a direct quote from the IMST report (page 27). Current rules require specific harvesting practices be employed on high-risk sites. These practices are designed primarily to limit ground disturbance so that the landslide risk will not be increased. The rules and/or guidance do not require practices that require merchantable trees to be left on the site to possibly play a role in stabilizing the slope either through a mechanical (root reinforcement) or hydrological (water routing) mechanisms. Additional silvicultural approaches that utilize the functions of vegetation could be made available for the management of high-risk sites, depending on risk to resources. The goal of these approaches is two-fold. Management prescriptions might be used to minimize the risk of landslide occurrence, and also to influence the quality of the landslide if/when it does occur (i.e., ensuring that large wood and sediment will deliver to the stream, as opposed to sediment without the large wood).

Since hazards and risks are variable, it is logical to develop practices consistent with the potential for landslide delivery to streams. The hazard is also related to the percent of the watershed that is subject to debris flows and in a condition with reduced forest cover. Managing the quality of high-risk sites (i.e., the amount of large wood left on the site) will potentially increase the amount of large wood delivered to streams.

Methods/Approaches:
Listed below are different methods that might be used to protect high-risk (hazard) sites during harvesting operations and subsequent stand management:

1) Standard practices defined in rule to include clearcut harvest with no hillslope alterations (skid roads, gouging) followed by rapid reforestation (the most common current practices). This may or may not require a written plan.
2) Written plans for harvesting operations on high-risk (hazard) sites prepared by a geoscience professional, with practices consistent with the level of risk to resources.
3) Leave trees that are likely to influence slope stability on high-risk (hazard) sites. (This is related to Method 1 under Option 61.)
4) Within a given watershed or ownership, limit the percent-area of high-risk (hazard) sites in a young age class.
5) A harvesting prohibition on some or all high-risk (hazard) sites (leave areas).
6) Continue to apply the current best management practices (BMP) approach to the management of forest lands with significant landslide potential and develop a better case history basis for evaluating the effectiveness of BMP in this area. (IMST Recommendation #14.)

Method 1

Benefits:
Based on results from Robison and others (1999), operators comply with current practices and minimize ground disturbance. It may also be possible to develop reforestation practices that further reduce the “window of increased landslide vulnerability” that occurs after timber harvesting on steep slopes. This would probably entail avoiding intense slash burns and applying herbicides so that nonconifer vegetation is not completely eliminated.

Costs:
Little or no additional costs to landowners. Landslide occurrence would occur at an increased rate for some period after harvesting, at least in most cases. This is likely to be followed by longer period of reduced landslide occurrence. Effects to fisheries would be watershed specific, depending on the components of the debris flow and its travel distance. It would be difficult to make practices contingent on risk to resources. Achieving “free-to-grow” reforested seedlings may be more difficult.

Method 2

Benefits:
Since hazards and risks are variable, it is logical to develop practices consistent with the potential for landslide delivery to streams. Geoscientist evaluation provides the best assessment of potential debris flow initiation and characteristics, and on relative risk to resources. If protection methods were contingent on risk, a geoscientist evaluation would be essential.

Costs:
Additional cost to landowner for the geoscientist evaluation. The required prescription may also have additional costs in terms of trees left or alternative yarding systems. In some cases, this option would include leaving merchantable trees. Most geoscientists have very limited understanding of forest harvesting systems or other forest practices, so development of specific prescriptions would be difficult.

Method 3

Benefits:
Since hazards and risks are variable, it is logical to develop practices consistent with the potential for landslide delivery to streams. Managing the quality of high-risk sites (i.e., the amount of large wood left on the site) will potentially increase the amount of large wood delivered to streams.

Costs:
There is no scientific information upon which to base the choice of different silvicultural options (the optimum mix of trees per acre, canopy closure, or other measure of retained trees). Management prescriptions will need to be tested over time to see if they are in fact achieving the desired objective. The cost to landowners is potentially high, as this could entail alternative management over large areas of forestland. Areas mapped as high debris flow hazards encompass hundreds of thousands of acres.

Method 4

Benefits:
The risk to resources (i.e., number of debris flows per unit area) is probably related to the percent of the watershed that is subject to debris flows and in a condition of reduced forest cover. This method will allow evaluation of risk at a watershed level.

Costs:
The cost to landowners is potentially high, as this could entail alternative management over large areas of forestland. Unless carefully crafted (for example, to consider each ownership separately), such a method could be seen as inconsistent with federal antitrust laws.

Method 5

Benefits:
Use of this method might prevent some or most of the temporary increase in landslide occurrence observed in Robison and others (1999) and in other landslide surveys. According to the “timing” theory, harvesting may increase short-term landslide occurrence, but may not affect long-term erosion.

Costs:
The cost to landowners is potentially very high, as this could preclude timber harvesting over large areas of forestland. Areas mapped as high debris flow hazards encompass hundreds of thousands of acres. Also, unless provided with a wind firm buffer, practices such as headwall-leave areas may increase the incidence of landslides. The prevalent notion that leaving a small number of trees on a high hazard site ignores the high probability of those trees blowing over and at the least negating any potential for reducing landslide occurrence on those sites.

Method 6

Benefits:
This is the IMST recommendation No. 14 and is similar to method No. 1 above.

Costs:
Little or no additional costs to landowners. Landslide occurrence would occur at an increased rate for some period after harvesting at least in most cases. This is likely to be followed by longer period of reduced landslide occurrence. Effects to fisheries would be watershed specific, depending on the components of the debris flow and its travel distance. It is not clear how a “case history basis for evaluating BMP effectiveness” could be developed, since it is unlikely that options different from standard practices will be commonly used.

Option #61: Large Wood Sources from Hillslope Areas and Seasonal Type N Streams

Objective:
To supply large wood inputs from seasonal Type N streams and hillslope areas that have the potential to deliver large wood to fish bearing streams of a quality and quantity sufficient to provide important habitat functions in those streams.

Description:
There is increasing scientific evidence that wood contained in debris flows is an important source of large wood for downstream fish habitat. These areas include likely debris flow paths, which are typically steep hillslopes below high-risk (hazard) sites, and above steep stream channels (a portion of small Type N streams). While these areas are providing some level of functional LW inputs under the current rules, the rules were not specifically designed to provide sources of LW from these areas. Action should be taken to increase the LW input potential from these areas.

There are two general strategies: Leave trees on the slope at potential initiation sites, or leave trees that are likely to enter fish bearing streams at some point below potential initiation sites.

Methods/Approaches:
Listed below are possible methods for the committee to consider:

1. Leave trees on high-risk (hazard) sites that are likely to deliver to Type F streams. Trees would be of a minimum age or diameter. (This is related to Method 3 under Option 47.)
2. Locate the in-unit leave trees currently required (two per acre) in hillslope and headwall areas below potential high-risk (hazard) sites that are likely to deliver to Type F streams.
3. Require additional leave trees to be located in hillslope and headwall areas below potential high-risk (hazard) sites that are likely to deliver to Type F streams. Trees would be of a minimum age or diameter.
4. Utilize a riparian management area (RMA) for small seasonal Type N channels that are prone to debris flows. (This method is currently proposed under the revised version of Option 38.)
5. Utilize a number of the options above, depending on the likelihood of wood delivery and on operational efficiency concerns.

Method 1

Benefits:
Trees in these locations have some potential to be carried by debris flows into stream channels. This is especially true for certain actively moving landslides.

Costs:
Except for actively moving landslides, these locations probably have a fairly low likelihood of delivering wood to stream channels, since individual sites fail very infrequently. Therefore, much of the value in trees retained on site may never provide a large wood function in streams.

Method 2
Benefits:
This method results in little or no increased cost to the landowner. Trees in these locations are likely to enter debris flow-prone channels.

Costs:
There is little or no current information on how many trees need to be left. This option may not provide what is considered an optimum wood volume. There may be other consequences for wildlife from moving in-unit trees to steep stream channels.

Method 3

Benefits:
Trees in these locations have some potential to be carried by debris flows into stream channels.

Costs:
These locations probably have a lower likelihood of delivering wood to stream channels.

Method 4

Benefits:
The RMA could supply a fairly continuous source of wood for debris flows that might occur. Trees in these locations have a high potential to enter debris flow-prone channels. These should also have a higher likelihood of being moved by a debris flow into larger Type F channels, where this wood may help the formation of both pools and gravel deposits.

Costs:
There are many very small channels subject to debris flows. Some of these channels have a low likelihood of delivering material to Type F streams. There is little or no current information on how many trees would need to be left.

Method 5

Benefits:
Wood delivery by debris flow depends on a number of factors. Using this method might allow the wood to be placed in the locations where it has the greatest potential to by moved be a debris flow to a place where it provides quality habitat.

Costs:
If additional leave trees were required, this would be an increased cost for landowners. There is currently no well-established methodology for deciding how many trees to leave or precisely where to leave them. A significant amount of analysis will be necessary if different scenarios are to be evaluated. There is currently no analysis for determining how much wood is sufficient, nor is there a mechanism (voluntary or regulatory, or some combination) to ensure sufficient wood will be left.

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Attachment

Table 1. Studies of comparative landslide ("L.S.") densities and erosion rates in recently harvested forests versus unharvested mature forests.

Reference	Site	Measurement Type*	Recently Harvested		Road Right of Way	
			Ratio L.S. Density	Ratio L.S. Erosion	Ratio L.S. Density	Ratio L.S. Erosion
Amaranthus et al., 1985	Siskiyou Mtn., Oregon	Air	19.0	6.8	138.0	111.0
Bishop and Stevens, 1964	S.E. Alaska, Maybeso Cr.	Air	19.5	NA	NA	NA
Bush et al., 1997	Oregon Coast Range	Air/Size	2.6	NA	31.6	NA
Chesney, 1982	Oregon Cascades, 1949	Air/Field Visit	0.0	NA	11.1	NA
" "	Oregon Cascades, 1959	Air/Field Visit	3.7	NA	33.3	NA
" "	Oregon Cascades, 1967	Air/Field Visit	12.9	NA	208.0	NA
" "	Oregon Cascades, 1972	Air/Field Visit	21.8	NA	705.0	NA
" "	Oregon Cascades, 1979	Air/Field Visit	4.7	NA	254.0	NA
Dyrness, 1967	Oregon Cascades, H.J. Andrews	Air/Size	9.8	5.0	309.0	60.1
Fiksdal, 1974	Olympic Pen. Washington, Sequaleho Cr.	Air/Field Visit	0.0	0.0	1600.0	224.0
Gresswell et al. 1979	Oregon Coast Range, Mapleton Area	Air/Field Visit	23.5	NA	72.2	NA
Hicks, 1982	Oregon Cascades, Middle Santiam	Air/Field Visit	3.6	3.4	73.7	95.3
Hughes and Edwards, 1978	Oregon Cascades, Umpqua basin	Ground	8.0	10.0	NA	NA
Johnson, 1991	Washington Cascades; S Fk. Canyon Cr.	Mixed	5.3	NA	97.0	NA
Ketcheson and Froehlich, 1978	Oregon Coast Range, Mapleton Area	Ground	2.2	3.4	NA	NA
Lyons, 1982	Oregon Cascades, 1959-67	Air/Field Visit	22.8	29.5	NA	NA
" "	Oregon Cascades, 1967-72	Air/Field Visit	6.8	10.0	NA	NA
Marion, 1981	Oregon Cascades, Blue River	Air/Field Visit	10.0	9.0	106.0	44.0
McHugh, 1987	S.W. Oregon	Air/Field Visit	7.0	NA	48.0	NA
Morrison, 1975	Oregon Cascades, Alder Creek	Air/Size	13.5	2.6	415.0	343.0

NA = Not available

Table 1 (Continued). Studies of comparative landslide ("L.S.") densities and erosion rates in recently harvested forests versus unharvested mature forests.

Reference	Site	Measurement Type*	Recently Harvested		Road Right of Way	
			Ratio L.S. Density	Ratio L.S. Erosion	Ratio L.S. Density	Ratio L.S. Erosion
Robison et al., 1999 (This study)	Oregon Cascades, near Vida	Ground	1.4	3.2	2.7	40.9
" "	Oregon Coast Range, Elk Creek	Ground	0.8	0.3	1.0	0.8
" "	Oregon Coast Range, Mapleton	Ground	1.9	1.5	5.0	13.6
" "	Oregon Coast Range, Scottsburg	Ground	5.2	2.6	NA	NA
Rood, 1984	British Columbia; Graham and Moresby Island	Air	30.0	31.2	76.7	89.7
Schroeder and Brown, 1984	Oregon Coast Range, Palouse Cr.	Air	9.6	NA	NA	NA
" "	Oregon Coast Range; Larson Cr.	Air	6.1	NA	NA	NA
Schwab, 1983	British Columbia, Queen Charlotte Islands	Mixed	17.0	5.0	41.0	46.0
Smith, 1996	Oregon Cascades; Weak Rock, Steep Slopes	Air	10.7	NA	NA	NA
Swanson and Dyrness, 1975	Oregon Cascades, H.J. Andrews Unstable	Mixed	3.2	2.8	33.0	30.0
Swanson and Grant, 1982	Oregon Cascades, WNF Mod. Stable	Mixed	3.0	2.5	47.0	37.0
" "	Oregon Cascades, WNF Unstable	Mixed	7.0	5.0	336.0	250.0
Swanson et al., 1977	Oregon Coast Range, Cedar Cr.	Mixed	1.2	NA	15.0	NA
" "	Oregon Coast Range, Soil Type 47	Mixed	1.3	4.0	15.5	30.8
Swanston and Swanson, 1976	S.W. British Columbia Coast Range	Air/Size	5.0	2.2	20.0	25.2

***Measurement types: 1. "Air" - Studies based on air photos with or without ground verification regarding the size of landslides and whether or not the feature was actually a landslide. 2. "Air/Size" – Studies based on air photos with a minimum landslide size used to decrease the chance of bias between old and young stands. 3. "Mixed" – Studies combine more that one method of detection. For instance, one study used air photos to detect landslides in clearcuts and a ground-based sample in older forests. 4. "Air/Field visit" – Studies using air-based sampling with informal field visits used to get some inclinations that most landslides are being found. 5. "Ground" – Studies that detect landslides based on a systematic sampling of all landslides using the channel network and/or an orderly walking of slope contours to search for landslides.**